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Cultural heritage and biodiversity conservation – plant introduction and practical restoration on ancient burial mounds

Orsolya Valkó[1], Katalin Tóth[2], András Kelemen[1,3], Tamás Miglécz[1,3], Szilvia Radócz[1], Judit Sonkoly[4], Béla Tóthmérész[1,2], Péter Török[4], Balázs Deák[2]

1 *University of Debrecen, Department of Ecology, Debrecen, Egyetem tér 1, H-4032 Hungary* **2** *MTA-DE Biodiversity and Ecosystem Services Research Group, Debrecen, Egyetem tér 1, H-4032 Hungary* **3** *MTA's Post Doctoral Research Programme, MTA TKI, Nádor utca 7, Budapest, H-1051 Hungary* **4** *MTA-DE Lendület Functional and Restoration Ecology Research Group, Egyetem tér 1, Debrecen, H-4032, Hungary*

Corresponding author: *Orsolya Valkó* (valkoorsi@gmail.com)

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Abstract

Linking the conservation of cultural heritage and natural values provides a unique opportunity for preserving traditional landscapes and receives an increased awareness from stakeholders and society. Ancient burial mounds are proper objects of such projects as they are iconic landscape elements of the Eurasian steppes and often act as refugia for grassland specialist species. The aim of this project was to reintroduce grassland plant species to burial mounds for representing them as cultural monuments with the associated biodiversity for the public. The effectiveness of seed sowing, transplanting greenhouse-grown plants and individuals from threatened populations on burial mounds in Hortobágy National Park, Hungary was tested. The following questions were answered: (1) which method is the most effective for species introduction? (2) which species can establish most successfully? (3) how does management affect the species establishment rates? It was found advisable to use a combination of seed sowing and transplanting greenhouse-grown plants. Sowing was found as a cost-effective method for introducing large-seeded species, whilst introduction of greenhouse-grown transplants warranted higher establishment rates for a larger set of species. Transplanting adult individuals was more reliable regardless of management regimes, however this method is labour-intensive and expensive. Intensive management, like mowing with heavy machinery and intensive grazing, should be avoided in the first few years after introduction. The authors

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highlighted the fact that introducing characteristic grassland species on cultural monuments offers a great opportunity to link issues of landscape and biodiversity conservation. This project demonstrated that, by the revitalisation of cultural monuments, cultural ecosystem services can also be restored.

Keywords
cultural ecosystem services; endangered species; grassland restoration; landscape conservation; landscape element; reintroduction

Introduction

Open landscapes often harbour surprisingly high biodiversity and they are also an essential part of our cultural heritage (Dengler et al. 2014). The European Landscape Convention was initiated to protect and sustain European landscapes characteristic of certain countries and cultures (Jones 2007). Protection of the traditional landscape structure and land use types can considerably contribute to biodiversity conservation by ensuring the optimum landscape configuration and proper management for semi-natural habitats (Babai and Molnár 2014, Plieninger et al. 2015, Szilassi et al. 2017). One of the major threats to European landscapes is the huge loss of habitats due to the intensive land use of past centuries (Lindborg et al. 2015, Hüse et al. 2016). In the near future, increasing demands for natural resources are expected to further accelerate the rate of habitat degradation and species extinctions (Guerrant et al. 2004). Since grasslands harbour an extraordinarily high diversity, their conservation and restoration are high-priority tasks (Valkó et al. 2016a).

Integrating cultural ecosystem services into landscape planning and protection can effectively support nature conservation projects which aim to conserve historical landscape elements with a potential of harbouring high biodiversity and providing ecosystem services (Jones et al. 2016, Ramos et al. 2016). Ancient burial mounds called 'kurgans' can serve as ideal objects for such projects. Kurgans are earthen burial mounds built by nomadic tribes from the Late Copper Age to the medieval period (Sudnik-Wójcikowska et al. 2011, Bede et al. 2015). They are iconic landscape elements of the Eurasian steppes and have a considerable role in the life of local people as historical and sacred places (Deák et al. 2016a, Sudnik-Wójcikowska et al. 2011). Their size ranges from a few hundred square metres to one hectare and their height is usually between 1 and 15 metres (Deák et al. 2016a). Their special shape makes them prominent landscape elements in plain areas. The estimated number of kurgans is 400–600,000 in the steppe region (Deák et al. 2016a), thus they can be considered as typical elements of the steppe biome.

Besides their cultural and aesthetic value, burial mounds often act as biodiversity hotspots in agricultural landscapes. Their particular shape and steep slopes have often prevented ploughing; thus, grassland vegetation has been able to survive on burial mounds (Deák et al. 2016b, Dembicz et al. 2016). This is especially true for loess grasslands which are often restricted to burial mounds and road verges in many regions

(Sudnik-Wójcikowska et al. 2011, Deák et al. 2016a, b). Given the importance of burial mounds in landscape protection and biodiversity conservation, they can serve as representative spots for the demonstration of the results of conservation projects. Their importance is acknowledged by the European Landscape Convention and they are considered typical landscape elements of Hungary (Jones 2007, Jones et al. 2016). Despite their legal protection, urbanisation and ploughing considerably threaten the vegetation of the burial mounds, thus in many cases active restoration measures are needed for their revitalisation (Deák et al. 2016a). Due to the scattered distribution and relatively small area of the burial mounds, small-scale and volunteer NGO projects can contribute considerably to preserving or restoring their biodiversity.

Spontaneous recovery of target plant populations in degraded landscapes is often hampered by propagule-limitation, i.e. the lack of target species in the seed banks and seed rain, as many grassland plant species have transient seed banks and many are dispersal-limited (Baur 2014). Thus, active management strategies such as reintroduction of plant populations to appropriate habitats have become increasingly integrated into conservation practice (Maunder 1992, Rout et al. 2009). However, in spite of this huge number of species introduction projects and the urgent need for best practices from the practitioner's side, there are only a few available studies in this topic (Bottin et al. 2007, Godefroid et al. 2011a). A search for scientific articles in the ISI Web of Knowledge using the keywords "plant species introduction" and "conservation" confined to the countries of the European Union, returned only 183 hits. These hits were screened by title and only 21 publications were found that concerned plant species introduction projects. Information is especially lacking about negative results and failures, however these can be highly informative for practitioners in order to avoid future problems (Godefroid et al. 2011b). Latter cases are of high importance as most of the species introduction projects are not considered as comprehensively successful, thus information about potential problems would be especially helpful in planning such projects (Allen 1994).

The authors introduced historically widespread species of loess grasslands on burial mounds with species-poor and degraded vegetation in the Hortobágy National Park, Hungary. An approach which was found to be effective in restored grasslands was used, i.e. creating establishment hot-spots for grassland specialist plant species (see also Valkó et al. 2016b), from where they are able to colonise the whole habitat patch. The overall aim was to introduce typical grassland species to create representative sites demonstrating burial mounds as landscape elements with the associated biodiversity for the public. Three methods were used for species introduction: seed sowing, planting individuals grown in greenhouses and translocating adult plants from threatened natural populations, which otherwise would probably become extinct. As it was primarily a conservation-focused and not a scientific project, species lists, sowing densities and the number of introduced individuals were determined according to the demands of the site manager. Due to the abovementioned reasons, it was not possible to run state-of-the-art statistical analyses which should be considered during the interpretation of the results. However publication of the authors' experiences was considered

of a high importance, as Godefroid et al. (2011b) also pointed out, a major problem is that in many cases results of non-scientific plant reintroduction projects remain in unpublished internal reports. The following questions were asked: (1) which method is the most effective for species introduction? (2) which species can establish most successfully? (3) how does management affect the establishment rate and flowering success of the target species?

Materials and methods

Study sites

The study sites are situated in the Great Hungarian Plain, in the Hortobágy National Park (N47.58°, E20.92°). The climate of the area is moderately continental with a mean annual temperature of 9.5 °C and mean annual precipitation of 550 mm (Lukács et al. 2015). The National Park is a UNESCO World Heritage site, due to the large areas of connected open landscapes and the associated traditional pastoral practices. Typically, burial mounds are covered by loess grassland vegetation (*Festucion rupicolae;* Deák et al. 2014). Due to their fertile chernozem soils, the majority of loess grasslands have been converted into arable fields in the region. They have mostly been preserved on sites unsuitable for arable farming, for example, on burial mounds.

Target species were reintroduced on to five burial mounds (see Table 1). All burial mounds harboured degraded and generally species-poor loess grasslands, characterised by grasses such as *Festuca rupicola*, *Poa angustifolia* and *Bromus inermis*. Several weedy species with good competitor abilities, which are unwanted from a nature conservation viewpoint, were present in the vegetation (*Bromus sterilis*, *Carduus acanthoides*, *Cirsium arvense*, *Lycium barbarum* and *Elymus repens*) and target forb species of loess grasslands were lacking. Two burial mounds with the steepest slopes (Filagória and Meggyes) were managed by the authors; they mowed the kurgans by a hand-held mowing machine three times a year (late April, mid-June and late August, every year from 2010 to 2015) and removed the hay by raking (Supplementary material 1). Two burial mounds with more gentle slopes (Nyíregyházi and Porosállás) were mown by heavy machinery, once a year

Table 1. Site characteristics of the studied kurgans.

	Filagória	Meggyes	Görbeszék	Nyíregyházi	Porosállás
Coordinates	N47.573271°, E20.942839°	N47.585222°, E20.973992°	N47.589589°, E20.872901°	N47.570090°, E20.951617°	N47.550524°, E20.881466°
Total area (m^2)	7500	4500	1600	10000	17000
Height (m)	7	2	8	5.5	2.5
Total vegetation cover (%)	78.0±10.4	84.0±6.6	77.0±5.8	78.0±5.7	87.0±5.7
Vegetation height (cm)	67.0±20.8	83.0±17.5	36.0±9.6	62.0±17.9	72.0±14.8
Management type	mown (hand)	mown (hand)	grazed (sheep)	mown (machinery)	mown (machinery)

in mid-June and the hay was removed by machinery. One burial mound (Görbeszék) was managed by extensive grazing by sheep; the grazing intensity was approximately 0.8 animal unit/ha. The grazing season lasted from late April to mid-October. The area which was affected by species reintroduction was approximately 0.25 ha in the studied kurgans.

Plant introduction

The aim of the project was to reintroduce characteristic loess grassland species to the studied burial mounds. Experts of the Hortobágy National Park Directorate selected the list of introduced species and also recommended the set of species to be reintroduced to certain kurgans. They selected a total of 18 species typical of the loess grasslands of the region. Three measures were applied for plant reintroduction: seed sowing, planting of individuals grown in the greenhouse (transplantation) and planting adult plants from threatened natural populations (translocation).

Seed collection

At the first stage of plant introduction, seeds of 16 target species were collected in 2013. Seeds originated from semi-natural loess grasslands of the region. The authors could not collect seeds of two endangered species (*Amygdalus nana* and *Anchusa barrelieri*), as from their few existing scattered populations, it was impossible to collect ripened viable seeds. For *Rosa rubiginosa*, seeds were collected before maturation (in late September) because, in that season, the amount of germination inhibitor compounds is lower in the pericarp (Haouala et al. 2013). The collected seed material was the basis for seed sowing (15 species) and also for growing individuals in a greenhouse (11 species). Germination tests were performed for all species; the germination rates of three sorts of 100 seeds per each species (altogether 300 seeds) were monitored from October 2013 to June 2014 (altogether 36 weeks).

Seed sowing

The collected seeds of herbaceous species were sown, after soil disturbance by raking in October 2013 (see Table 2). Scarification or stratification was not applied on the seeds of herbaceous species. Three characteristic species of loess grasslands (*Filipendula vulgaris*, *Salvia austriaca* and *S. nemorosa*) were sown as matrix forb (amount of 500 g seeds per burial mound). Other species were sown in an amount of 20 g seeds per burial mound.

Transplantation

Using the collected seed material, individuals of 11 target species were grown in a greenhouse (see Table 2). The seeds were sown in pots in March 2014. The only exception was *Rosa rubiginosa* which was sown in November 2013 and was grown under outdoor conditions because cold stratification has proved to be an effective method for breaking the seed dormancy of rose species (Zhou and Bao 2011). Germinated plants

Table 2. List of species introduced on the five kurgans. (A) Sown species and the amount of sown seeds (g), (B) Species list and number of greenhouse-grown transplants and (C) Species list and number of individuals translocated from threatened natural populations. Matrix species are marked with an asterisk.

	Filagória	Görbeszék	Meggyes	Nyíregyházi	Porosállás
(A) Seed sowing					
Carthamus lanatus		20 g	20 g		
Centaurea pannonica	20 g		20 g	20 g	20 g
Centaurea sadleriana	20 g	20 g		20 g	
Centaurea solstitialis	20 g		20 g		
Dianthus pontederae	20 g		20 g	20 g	20 g
*Filipendula vulgaris**	500 g		500 g	500 g	500 g
Galium verum	20 g				
Hypericum perforatum	20 g				
Knautia arvensis	20 g				
Lotus corniculatus					20 g
Lycopsis arvensis			20 g		
Phlomis tuberosa	20 g	20 g	20 g	20 g	20 g
*Salvia austriaca**	500 g		500 g	500 g	500 g
*Salvia nemorosa**	500 g		500 g	500 g	500 g
Silene vulgaris	20 g		20 g	20 g	
(B) Transplantation					
Carthamus lanatus		30			
Centaurea pannonica	38		30		
Centaurea sadleriana	50	45		50	
Centaurea solstitialis					
Dianthus pontederae	20		20	30	50
Filipendula vulgaris	20		20	30	50
Lotus corniculatus					34
Rosa rubiginosa	49				
Salvia austriaca			10	20	50
Salvia nemorosa	30		10	20	50
Silene vulgaris	36		20		
(C) Translocation					
Amygdalus nana	35			25	
Anchusa barrelieri				32	
Phlomis tuberosa	32	124	10	53	20

were transplanted to the kurgans in early September 2014. All transplants were marked with sticks and were watered for one week after transplanting to facilitate rooting and acclimatisation. The average temperature of the region was 17.3°C, and there was 54 mm precipitation in that month (HCSO 2017). In November 2014, mulching (using an approximately 0.5 cm thick layer of hay) was applied at the basal parts of the stems in order to prevent freezing.

Translocation

In the case of three endangered species, adult plants were translocated to the kurgans from endangered natural populations in the region (Table 2). The individuals of *Amygdalus nana* and *Phlomis tuberosa* were translocated from populations situated in road verges which were threatened both by intensive mowing and herbicide application. The individuals of *Anchusa barrelieri* originated from the margin of an arable field and were threatened by ploughing and fertiliser run off. Individuals were translocated in September 2013. All translocated individuals were marked with sticks and were treated similarly (watering and mulching) to the greenhouse grown transplants (Supplementary material 1).

Sampling of introduction success

The survival rate of introduced species was tested in September 2015 by counting all individuals. To evaluate reproductive success, the species which flowered or set seeds in September 2015 were listed. For sown species, the establishment rates were calculated as follows. From germination rates in the greenhouse experiment, the predicted numbers of individuals were calculated on the burial mounds using the following equation: $N_p = SN_s \times (N_g/100)$, where N_p is the predicted number of individuals per burial mound; SN_s is the number of seeds sown on burial mounds and N_g is the number of germinated individuals in the greenhouse experiment. The observed number of individuals were compared with the predicted numbers of individuals. For transplanted and translocated species, the establishment rate was calculated as the ratio of planted individuals/surviving individuals.

Results

The results of the germination experiment showed that the majority of species had good germination rates under greenhouse conditions, regardless of their thousand-seed weights (Supplementary material 1). The observed establishment rates of sown species on the burial mounds were lower than the predicted values (a mean of 0.55 % ± 2.57 SD; Table 3). The establishment rate of sown species was the highest on the two burial mounds (Filagória and Meggyes) which were managed by hand mowing (Table 3). Only two sown species (*Carthamus lanatus* and *Lycopsis arvensis*) had an establishment rate higher than 10% on at least one burial mound. These two species were those with the highest thousand-seed weights (Supplementary material 1). There were six species (*Centaurea pannonica*, *C. sadleriana*, *Dianthus pontederae*, *Filipendula vulgaris*, *Lotus corniculatus* and *Phlomis tuberosa*) which failed to establish on any of the burial mounds after seed sowing (Table 3).

The establishment rate of transplanted plants was the highest on the two burial mounds (Filagória and Meggyes) which were managed by hand mowing (Table 3). The highest establishment rates were detected for *Rosa rubiginosa*, *Salvia austriaca* and *S. nemorosa*. There were three species (*Carthamus lanatus*, *Dianthus pontederae* and *Lotus corniculatus*) which failed to establish on any of the burial mounds.

Table 3. Establishment rates in September 2015 (%) of (A) sown species, (B) greenhouse-grown transplants and (C) individuals translocated from threatened natural populations. Species which had flowering individuals are marked with an asterisk.

	Filagória	Görbeszék	Meggyes	Nyíregyházi	Porosállás
(A) Seed sowing					
Carthamus lanatus		0.00	12.61*		
Centaurea pannonica	0.00		0.00	0.00	0.00
Centaurea sadleriana	0.00	0.00		0.00	
Centaurea solstitialis	0.11*		0.75*		
Dianthus pontederae	0.00		0.00	0.00	0.00
Filipendula vulgaris	0.00		0.00	0.00	0.00
Galium verum	0.08*				
Hypericum perforatum	0.02*				
Knautia arvensis	0.24*				
Lotus corniculatus					0.00
Lycopsis arvensis			10.68*		
Phlomis tuberosa	0.00	0.00	0.00	0.00	0.00
Salvia austriaca	0.51*		0.03*	0.00	0.01
Salvia nemorosa	0.37*		0.33*	0.01	0.02
Silene vulgaris	0.03*		0.00	0.00	
(B) Transplantation					
Carthamus lanatus		0.00			
Centaurea pannonica	10.50*		3.30*		
Centaurea sadleriana	8.00	51.10*		0.00	
Dianthus pontederae	0.00		0.00	0.00	0.00
Filipendula vulgaris	10.00		0.00	0.00	0.00
Lotus corniculatus					0.00
Rosa rubiginosa	75.50				
Salvia austriaca			60.00*	5.00	6.00
Salvia nemorosa	100.00*		90.00*	10.00*	36.00*
Silene vulgaris	5.60*		0.00		
(C) Translocation					
Amygdalus nana	37.10			0.00	
Anchusa barrelieri				56.30*	
Phlomis tuberosa		66.10*		75.50*	75.00*

Establishment rates of individuals translocated from threatened natural populations were higher than 50% on all sites for *Anchusa barrelieri* and *Phlomis tuberosa* (Table 3). The establishment rate of *Amygdalus nana* was 37.1 % on Filagória kurgan, managed by hand-mowing. The species failed to establish on Nyíregyházi kurgan, which was managed by mowing machinery.

Altogether, 12 species having individuals with flowering shoots were found. The highest proportion of flowering species was found on burial mounds managed by hand mowing (Filagória and Meggyes). Of the established species, *Amygdalus nana*, *Filipendula vulgaris* and *Rosa rubiginosa* failed to flower on any of the kurgans.

Discussion

The study demonstrated that all three methods (seed sowing, transplanting and translocating) were feasible for plant introduction. Based on these results, several circumstances, such as site conditions, management type, species characteristics, available manpower and financial limitations should be considered when choosing the most feasible method.

Seed sowing

Sowing the seeds of target species is considered to be the least labour- and cost-intensive method for species introductions (Guerrant and Kaye 2007). However, this study and several other papers reported that seed sowing has the lowest success rate amongst the widely applied plant introduction methods, because seed germination in the field is influenced by many factors and is often rather unpredictable (Menges 2008, Becker 2010). It was found that the success of seed sowing largely depended on specific germination features, management and local environmental conditions. Besides these factors, the introduction success also depends on the timespan of the monitoring. For instance, several seeds, especially those with a hard seed coat, germinate after several years of dormancy in natural conditions (Baskin and Baskin 1998). Thus, these seeds might be able to germinate in the future years.

The quality of the collected seed material was assessed by the germination success of all target plant species from which viable seeds could be collected. It was found that the seeds of all collected species germinated under greenhouse conditions, however, species with a hard seed coat (*Lotus corniculatus*, *Lycopsis arvensis*, *Phlomis tuberosa* and *Salvia austriaca*) and most species of the family *Asteraceae* (*Carthamus lanatus*, *Centaurea pannonica* and *C. sadleriana*) had moderate germination rates in the greenhouse. On the one hand, as many of these species require some mechanism to break seed dormancy (Baskin and Baskin 1998), in future projects, testing scarification or stratification measures on such seeds is recommended in order to increase their establishment success. On the other hand, seed predator insects often consume the seeds of these species (Steffan-Dewenter et al. 2001) and, even though the seed material of infested seeds was carefully cleaned, some of them remained in the seed material.

It was found that species with high thousand-seed weights (especially *Carthamus lanatus* and *Lycopsis arvensis*) could establish most successfully on the burial mounds. It was also found in former studies that species with large seeds can better tolerate the shading effect of litter and can also germinate below thick litter layers (Miglécz et al. 2013). Litter accumulation is typical in the loess grasslands of the region; Kelemen et al. (2013) reported amounts of litter ranging between 161–516 g/m^2. This suggests that large-seeded species can have an establishment advantage compared to small-seeded ones under such conditions (see also Ambika et al. 2014). Therefore, sowing species with large seeds is advisable in such projects and, by the application of these species, the cost efficiency of the project can be increased.

In many cases, seeds failed to germinate due to the lack of proper establishment microsites (see also Deák et al. 2011). It was found that seed sowing was most effective on burial mounds which were managed by hand mowing. Hand mowing usually creates a

higher diversity of microsites favourable for plant germination compared to the homogeneous vegetation structure formed by mowing machinery (Humbert et al. 2009). In the study sites, hand mowing was performed three times a year, which supported higher vegetation openness compared to kurgans mown once a year by machinery. More frequent hand mowing was likely to be more effective in weed control than less frequent mowing by machinery and, at the early mowing dates, weeds could be removed before their seeds ripened (Kelemen et al. 2014). By hand mowing, it was also possible to give an advantage to introduced species by avoiding cutting them before seed ripening. Grazing is usually associated with a higher trampling disturbance than hand mowing (Tälle et al. 2016, Tóth et al. 2016) resulting in the failure of germination of the sown species on the grazed Görbeszék kurgan. Based on these findings, for the effective introduction of target species by seed sowing, either hand mowing or soil preparation by raking or smooth harrowing is necessary (Klaus et al. 2017, Valkó et al. 2016b). Higher flowering ratio of introduced species on hand mown sites compared to the sites mown by machinery also shows the advantages of hand mowing versus mowing by machinery.

Even though seed sowing is considerably less labour-intensive than the transplanting of individuals, important drawbacks of the method were identified. The success of seed sowing largely depends on the germination rates of the available seed material (see also Godefroid et al. 2011a). In many cases, it is difficult to harvest viable seeds from certain species, especially from rare ones (such as *Anchusa barrelieri* and *Amygdalus nana* in this study). This is due to the fact that they usually have small and scattered populations and often one of the reasons for their vulnerability is the low seed production itself (Bottin et al. 2007). Thus, seed sowing cannot be an option for the reintroduction of species with low availability of ripened seeds or very low germination rates. Given the abovementioned drawbacks, seed sowing can be recommended only in certain cases. It can be a feasible option in the case of large-seeded species, which can tolerate litter accumulation, or on sites where the availability of establishment microsites is high, but the intensity of trampling and biomass removal is moderate.

Transplanting and translocation

Both transplanting of juvenile and adult plants proved to be a more effective method than seed sowing, as individuals are introduced at a more developed ontogenetic stage which increases the probability of successful establishment (Guerrant and Kaye 2007, Wallin et al. 2009). However, it should be considered that, even though transplantation and translocation were successful in the first year, dynamics might be different in following years. Even though transplanting adult individuals is considerably more labour-intensive and expensive than seed sowing, this method was more reliable and less sensitive to site characteristics and management regimes. The most successful establishment was found in the case of species with well-developed root systems or belowground storage organs, such as *Salvia austriaca*, *S. nemorosa*, *Phlomis tuberosa*, *Amygdalus nana* and *Anchusa barrelieri* (Kutschera et al. 1992).

By translocation, individuals of the threatened donor populations could be saved. All three species which were translocated from threatened natural populations estab-

lished successfully and two of them (*Anchusa barrelieri* and *Phlomis tuberosa*) had flowering and fruiting individuals on the burial mounds and were thus able to establish a new population on the recipient site. This result indicates the importance of this kind of conservation action which aims to translocate individuals from threatened populations to suitable habitats.

Plants are in a sensitive period for a few months after transplantation and translocation; thus, in this early period, intense disturbance, such as trampling, mowing or grazing should be avoided (Bottin et al. 2007). Besides, transplantation and translocation themselves are often associated with small-scale soil disturbance and these disturbed soil surfaces can be starting points for weed encroachment (Török et al. 2012). As mowing and grazing are not feasible management options in the very close vicinity of recently planted individuals, weeds growing close to the planted plants were suppressed by cutting them with pruning shears.

Implications for nature conservation

Based on these results, in plant introduction projects, it is crucial to collect basic seed material from a local provenance and to test the germination ability of seeds. One part of the seeds can be used for seed sowing on the field and the other part should be germinated in a greenhouse. In the case of larger seeded species, greater success with seed sowing than in the case of smaller-seeded ones can be expected. With transplanting and translocating individuals, the establishment success can be increased, but it is crucial to ensure proper water availability and protect the transplants from severe disturbance.

Godefroid et al. (2011a, b) pointed out that there is a considerable publication bias in plant introduction studies: usually only the successful results are published. Experiences of failures or problems generally remain unavailable to the public, even though they would be very useful for planning and implementing plant introduction projects. In this case, most of the difficulties were associated with improper management (use of mowing machinery) or too intense competition by neighbouring vegetation (see also Kelemen et al. 2015). These results suggest that post-introduction management is a crucial factor which has to be carefully planned and implemented in future projects. In the first year after introduction, mowing by machinery or grazing should be avoided, as these management types are associated with too intense non-selective trampling and biomass removal. Mowing by hand proved to be the best management option in the first few years, because in this way, the mowing of young transplanted individuals which are at a life stage highly sensitive to disturbance could be avoided. Later on, both grazing and mowing can be viable management options, depending on site characteristics, grassland type and available resources (Tälle et al. 2016).

This study demonstrated that landscape and biodiversity conservation can be linked by species reintroduction projects in historical landscapes. For such projects, burial mounds are ideal objects because they can act as representative spots for society.

These results draw attention to the necessity of restoring the landscape and biodiversity values of kurgans which are important parts of the cultural heritage across Eurasia. The need to link conservation and introduction programmes on cultural monuments should be emphasised.

To support future plant reintroduction projects, the following findings should be considered:

Seed material should be collected from regional populations to ensure the use of locally adapted ecotypes. Before large-scale application, indoor germination tests are recommended.

The use of a combination of seed sowing and transplanting greenhouse-grown plants is advisable. Seed sowing is a cost-effective method for introducing large-seeded species, whilst introduction of greenhouse-grown transplants warrants higher establishment rates for a larger set of species.

To create proper microsites for germination and establishment, it is crucial to lightly disturb the soil surface by raking prior to seed sowing.

As post-introduction management, regular watering and mulching is necessary to prevent drought, freezing and weed invasion after transplanting.

Intensive management, such as mowing with heavy machinery and intensive grazing, should be avoided in the first few years after introduction.

This project demonstrated that by the revitalisation of cultural ecosystem services, such as aesthetic values, public relations and educational values, can be restored at the same time (Plieninger et al. 2013). During the project, several layers of society could be involved. Several volunteers participated in the re-introduction and post-management actions. Due to the increased public awareness, the restored kurgans became part of the public demonstration route system in the Hortobágy National Park. By demonstrating the natural and cultural values of these cultural monuments, a wider society will become familiar with the historical, natural and landscape values of these monuments. Two of the restored kurgans became involved in the field courses of Hungarian and foreign institutes of higher education, representing the technical details of plant re-introduction and their nature conservation advances. In a few years, it will be possible to re-introduce moderate grazing, which is the traditional land use in the area and which is beneficial for local farmers, who can make use of the area.

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Supplementary material 1

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Authors: Orsolya Valkó, Katalin Tóth, András Kelemen, Tamás Miglécz, Szilvia Radócz, Judit Sonkoly, Béla Tóthmérész, Péter Török, Balázs Deák

Data type: (measurement/occurence/multimedia/etc.)

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